B.4 CONSTRUCTED WETLANDS

DESCRIPTION

Wetlands provide physical, chemical, and biological water quality treatment of stormwater runoff. Physical treatment occurs as a result of decreasing flow velocities in the wetland, and is present in the form of evaporation, sedimentation, adsorption, and/or filtration. Chemical processes include chelation, precipitation, and chemical adsorption. Biological processes include decomposition, plant uptake and removal of nutrients, plus biological transformation and degradation. Hydrology is one of the most influential factors in pollutant removal due to its effects on sedimentation, aeration, biological transformation, and adsorption onto bottom sediments (Dormann, et al., 1988). The large surface area of the bottom of the wetland encourages higher levels of adsorption, absorption, filtration, microbial transformation, and biological utilization than might normally occur in more channelized water courses.

A natural wetland is defined by examination of the soils, hydrology, and vegetation which are dominant in the area. Wetlands are characterized by the substrate being predominantly undrained hydric soil. A wetland may also be characterized by a substrate which is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year. Wetlands also usually support hydrophytes, or plants which are adapted to aquatic and semiaquatic environments. Natural and artificial wetlands are used to treat stormwater runoff. Figure 1 illustrates an artificial wetland used for treating stormwater runoff.

The success of a wetland will be much more likely if some general guidelines are followed. The wetland should be designed such that a minimum amount of maintenance is required. This will be affected by the plants, animals, microbes, and hydrology. The natural surroundings, including such things as the potential energy of a stream or a flooding river, should be utilized as much as possible. It is necessary to recognize that a fully functional wetland cannot be established spontaneously. Time is required for vegetation to establish and for nutrient retention and wildlife enhancement to function efficiently. Also, the wetland should approximate a natural situation as much as possible, and unnatural attributes, such as a rectangular shape or a rigid channel, should be avoided (Mitsch and Gosselink, 1993).

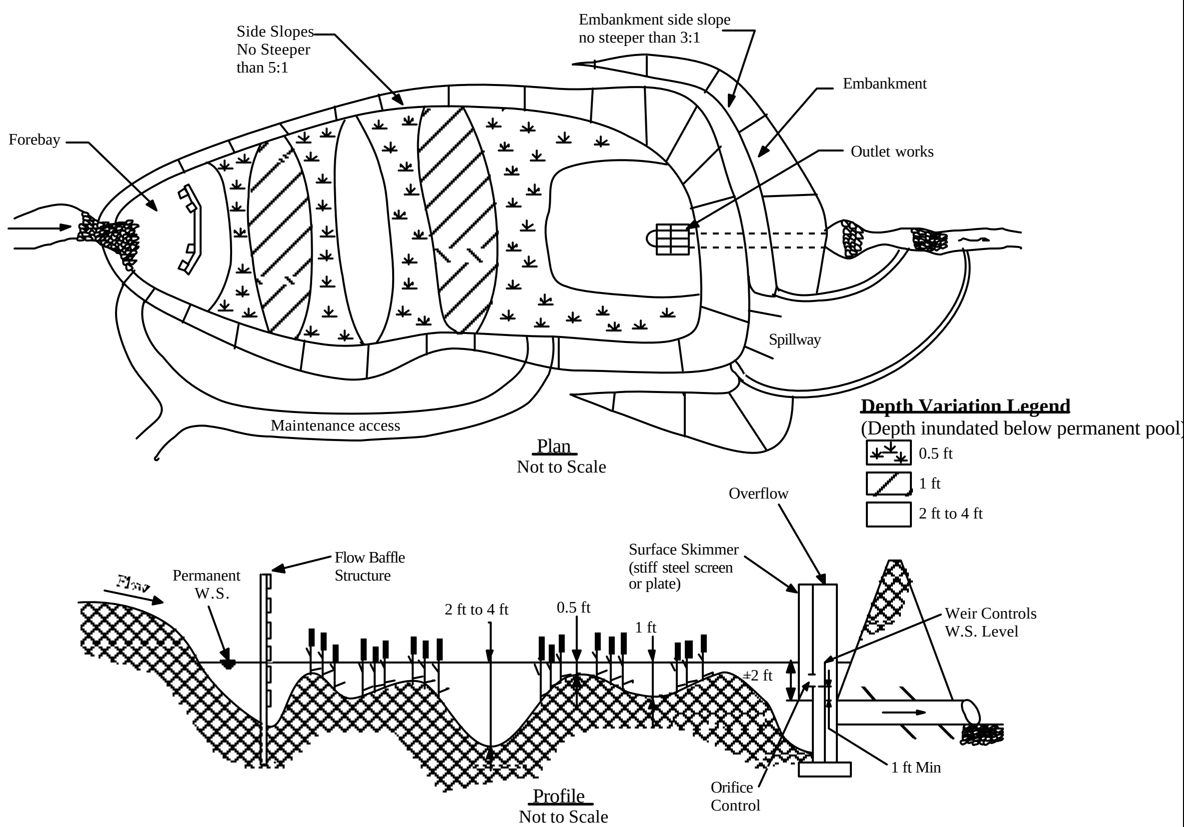


Figure 1. Plan and profile of a wetland pond (adapted from Urbanos, 1992).

1. *Natural Wetland Systems.* If a natural wetland site is potentially available for use to treat stormwater runoff, an assessment should be done to determine whether treatment of stormwater runoff would be appropriate. Important characteristics to look for in a potential natural wetland site include the wetland vegetation, the type of wetland, the existing wetland hydrology, and the geomorphology at the potential site.

   Wetland vegetation can be categorized as either emergent, floating, or submerged. Emergent vegetation is rooted in the sediments, but grows through the water and above the water surface. Floating vegetation is not rooted in the sediments, and has aquatic roots with plant parts partly submerged or fully exposed on the water or surface. Submerged vegetation includes aquatic plants such as algae or plants rooted in the sediments, with all plant parts growing within the water column. Pollutant removal rates generally improve with an increase in the diversity of the vegetation.

   The depth of inundation will contribute to the pollutant removal efficiency. Generally, shallow water depths allow for higher pollutant removal efficiencies due to an increased amount of adsorption onto bottom sediments (Dormann, et al.,1988). The water budget of the wetland should be calculated to determine the mean residence time of the wetland, assuming there is no change in storage. Water budget calculations should include precipitation, overland flow from other sources, groundwater, evapotranspiration, and any stormwater runoff into and out of the wetland. Flow patterns in the wetland will affect the removal efficiency also. Meandering channels, slow-moving water and a large surface area will increase pollutant removal through increased sedimentation. Shallow, sheet flow also increases the pollutant removal capabilities, through assimilative processes. A deep pool sometimes improves the denitrification potential. A mixed flow pattern will increase overall pollutant removal efficiency (Dormann, et al., 1988).

2. *Artificial wetlands.* Site considerations should include the water table depth, soil/substrate, and space requirements. Because the wetland must have a source of flow, it is desirable that the water table is at or near the surface. This is not always possible. If runoff is the only source of inflow for the wetland, the water level often fluctuates and establishment of vegetation may be difficult. The soil or substrate of an artificial wetland should be loose loam to clay. A perennial base flow must be present to sustain the artificial wetland. The presence of organic material is often helpful in increasing pollutant removal and retention.

   Using a site where wetlands previously existed or where nearby wetlands still exist is recommended if possible. A hydrologic study should be done to determine if flooding occurs and saturated soils are present. A site where natural inundation is frequent is a good potential site (Mitsch and Gosselink, 1993). Loamy soils are required to permit plants to take root (Urbonas, 1992)

ADVANTAGES

1. Artificial wetlands offer natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal.
2. Artificial wetlands can offer good treatment following treatment by other BMPs, such as wet ponds, that rely upon settling of larger sediment particles (Urbonas, 1992). They are useful for large basins when used in conjunction with other BMPs.
3. Wetlands which are permanently flooded are less sensitive to polluted water inflows because the ecosystem does not depend upon the polluted water inflow.
4. Can provide uptake of soluble pollutants such as phosphorous, through plant uptake.
5. Can be used as a regional facility.

LIMITATIONS

1. Although the use of natural wetlands may be more cost effective than the use of an artificial wetland; environmental, permitting and legal issues may make it difficult to use natural wetlands for this purpose.

2. Wetlands require a continuous base flow.
3. If not properly maintained, wetlands can accumulate salts and scum which can be flushed out by large storm flows.
4. Regular maintenance, including plant harvesting, is required to provide nutrient removal.
5. Frequent sediment removal is required to maintain the proper functioning of the wetland.
6. A greater amount of space is required for a wetland system than is required for an extended/dry detention basin treating the same amount of area.
7. Although artificial wetlands are designed to act as nutrient sinks, on occasion, the wetland may periodically become a nutrient source.
8. Wetlands which are not permanently flooded are more likely to be affected by drastic changes in inflow of polluted water.
9. Cannot be used on steep unstable slopes or densely populated areas.
10. May be regulated under Chapter 15, Title 23, California Code of Regulations regarding waste disposal to land.
11. Threat of mosquitoes.
12. Hydraulic capacity may be reduced with plant overgrowth.

DESIGN CRITERIA

The wetland may be designed as either a stand-alone BMP, or as part of a larger non-point source treatment facility in conjunction with other devices, such as a wet pond, sediment forebay, or infiltration basin. Basic design elements and considerations are listed below.

1. *Volume.* The wetland pond should provide a minimum permanent storage equal to three-fourths of the water quality control volume. The full water quality capture volume should be provided above the permanent pool. Calculate the water quality volume to be mitigated by the wetland using the Los Angeles County Department of Public Works *Method for Calculating Standard Urban Stormwater Mitigation Plan (SUSMP) Flow Rates and Volumes Based on 0.75-inches of Rainfall*.
2. *Depth.* A constant shallow depth should be maintained in the wetland, at approximately 1 ft or less (Schueler, 1987; Boutiette and Duerring, 1994), with 0.5 ft being more desirable (Schueler, 1987). If the wetland is designed as a very shallow detention pond, the pond should provide the full water quality capture volume above the permanent pool level. The permanent wetland depth should be 6 to 12 inches deep. The depth of the water quality capture volume above the permanent pool should not exceed 2 ft (Urbonas, 1992). Regrading may be necessary to allow for this shallow depth over a large area.

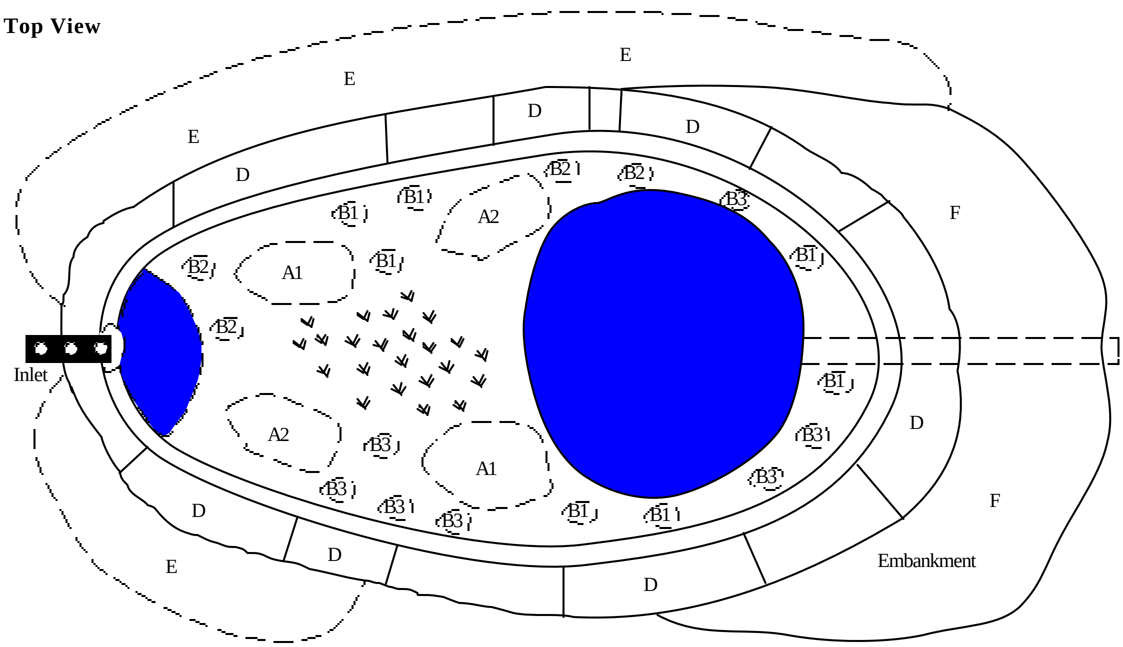
   It may also be beneficial to create a wetland with a varying depth. A varying depth within the wetland will enable more diverse vegetation to flourish. Deep water offers a habitat for fish, creates a low velocity area where flow can be redistributed, and can enhance nitrification as a prelude to later denitrification if nitrogen removal is desired. Open-water areas may vary in depth between 2 and 4 ft (Urbonas, 1992).

3. *Surface Area.* Increasing the surface area of the pond increases the nutrient removal capability (Boutiette and Duerring, 1994). A general guideline for surface area is using a marsh area of two to three percent of the contributing drainage area. The minimum surface area of the pond can also be calculated by determining the nutrient loading to the wetland. The nutrient loading to a wetland used for stormwater treatment should not be more than 45 lbs/ac of phosphorus or 225 lbs/ac of nitrogen per year. The pond could be sized to meet this minimum size requirement if the annual nutrient load at the site is known (Schueler, 1987).
4. *Longitudinal Slope.* Both wetland ponds and channels require a near-zero longitudinal slope (Urbonas, 1992).
5. *Base flow.* Enough inflow must be present in the wetland to maintain wetland soil and vegetation conditions. A base flow should be used. Dependence on groundwater for a moisture supply is not recommended.
6. *Seeding.* It is important that any seed which is used to establish vegetation germinate and take root before the site is inundated, or the seeds will be washed away.
7. *Length to Width Ratio.* The pond should gradually expand from the inlet and gradually contract toward the outlet. The length to width ratio of the wetland should be 2:1 to 4:1, with a length to width ratio of 3:1 recommended (Urbonas, 1992)
8. *Emptying Time.* The water quality volume above the permanent pool should empty in 24 hours (Urbonas, 1992). This emptying time is not for the wetland itself, but for the additional storage above the wetland.
9. *Inlet and Outlet Protection.* Inlet and outlet protection should be provided to reduce erosion of the basin. Velocity should be reduced at the entrance to reduce resuspension of sediment by using a forebay. The forebay should be approximately 5 to 10 percent of the water quality capture volume. The outlet should be placed in an offbay at least 3 ft deep. It may be necessary to protect the outlet with a skimmer shield that starts approximately one-half of the depth below the permanent water surface and extends above the maximum capture volume depth. A skimmer can be constructed from a stiff steel screen material that has smaller openings than the outlet orifice or perforations.
10. *Infiltration Avoidance.* Loss of water through infiltration should be avoided. This can be done by compacting the soil, incorporating clay into the soil, or lining the pond with artificial lining.
11. *Side Slopes.* Side slopes should be gradual to reduce erosion and enable easy maintenance. Side slopes should not be steeper than 4:1, and 5:1 is preferable (Urbonas, 1992).
12. *Open Water.* At least 25 percent of the basin should be an open water area at least 2 ft deep if the device is exclusively designed as a shallow marsh. The open water area will make the marsh area more aesthetically pleasing, and the combined water/wetland area will create a good habitat for waterfowl (Schueler, 1987). The

combination of forebay, outlet and free water surface should be 30 to 50 percent, and this area should be between 2 and 4 ft deep. The wetland zone should be 50 to 70 percent of the area, and should be 6 to 12 inches deep (Urbonas, 1992).

13. *Freeboard.* The wetland pond should be designed with at least 1 ft of freeboard (Camp, Dresser and McKee, 1993).
14. *Use with Wet Pond.* Shallow marshes can be established at the perimeter of a wet pond by grading to form a 10 to 20 ft wide shallow bench. Aquatic emergent vegetation can be established in this area. A shallow marsh area can also be used near the inflow channel for sediment deposition (Schueler, 1987).
15. *Shape.* The shape is an important aspect of the wetland. It is recommended that a littoral shelf with gently sloping sides of 6:1 or milder to a point 24 to 28 inches below the water surface (Mitsch and Gosselink, 1993). Bottom slopes of less than one percent slope are also recommended.
16. *Soils*. Clay soils underlying the wetland will help prevent percolation of water to groundwater. However, clay soils will also prevent root penetration, inhibiting growth. Loam and sandy soils may then be preferable. A good design may be use of local soils at the upper layer with clay beneath to prevent infiltration (Mitsch and Gosselink, 1993).
17. *Vegetation.* Vegetation must be established in the wetland to aid in slowing down velocities, and nutrient uptake in the wetland. A dependable way of establishing vegetation in the wetland is to transplant live plants or dormant rhizomes from a nursery. Emergent plants may eventually migrate into the wetland from upstream, but this is not a reliable source of vegetation. Transplanting vegetation from existing wetland areas is not encouraged, as it may damage the existing wetland area. Seeding is more cost effective, but is also not reliable.

    Plants which should be planted on the wetland bottom include cattails, sedges, reeds, and wetland grasses. Berms and side-slopes should be planted with native or irrigated turf-forming grasses. To allow the vegetation to establish, it may be necessary to initially lower the permanent pool, perhaps 3 to 4 inches.



LEGEND A1: Primary Wetland Species
A2: Primary Wetland Species
B1: Secondary Wetland Species
B2: Secondary Wetland Species
B3: Secondary Wetland Species
C: Deep Open Water Areas (No Vegetation)
D: Shoreline Fringe of Switchgrass, 50% of Safety Bench Perimeter
E: Wildlife Trees and Shrubs in Bugger
F: Maintain Grass Cover on Embankment (No Trees)

Figure 2. Examples of shallow marsh planting strategies (adapted from Schueler, 1987).

Table 1. Wetland plant species (Schueler, 1987).

Plant Name	*Zone*	*Form*	*Tolerance for Periodic Inundation*	*Comments*
Arrow Arum/ Duck Corn (Peltandra virginica)	2	Emergent	to 1 ft depth	Slow colonizer
Arrowhead/ Duck Potato (Saggitaria latifolia	2	Emergent	to 1 ft to 1.5 ft depth	Aggressive colonizer
Buttonbush (Cephalanthus occidentalis)	2, 3	Emergent	to 2 ft depth	Full sun required
Broomsedge (Andropogon virginianus)	2, 3	Perimeter	to 3 in depth	tolerates fluctuating water levels

Cattail (Typha spp.)	2, 3	Emergent	to 1 ft depth	Volunteer, aggressive colonizer
Coontail (Ceratophyllum demersum)	1	Submergent	1 ft to 6 ft deep	
Common Three-Square (Scirpus americanus)	2	Emergent	to 6 in deep	Fast colonizer, tolerates fluctuating water levels
Lizard's Tale (Saururus cernuus)	2	Emergent	to 1 ft	Rapid growing, shade tolerant
Marsh Hibiscus (Hibiscus moscheutos)	2, 3	Emergent	to 3 in	
Pickerelweed (Pontederia cordata)	2, 3	Emergent	to 0.5 ft to 1.0 ft	
Pond Weed (Potamegaton)	2, 3	Submergent	1.5 ft to 3.0 ft deep	
Rice Cutgrass (Leersia oryzoides)	2, 3	Emergent	to 3 in deep	Shade tolerant
Sedges (Cyperus spp.)	2, 3	Emergent	to 3 in deep	
Soft-stem Bulrush (Scirpus validus)	2, 3	Emergent up to 3 m	to 1.0 ft	Aggressive colonizer
Smartweed (Polygonum spp.)	2	Emergent	to 1 ft deep	Fast colonizer
Spatterdock (Nuphar luteum)	2	Emergent	to 1.5 ft	Fast colonizer, deals with fluctuating water levels
Switchgrass (Panicum virgatum)	2, 3, 4, 5, 6	Perimeter emergent	to 3 in deep	Tolerates wet/dry conditions
Sweet Flag (Acorus calamus)	2, 3	Perimeter emergent 2 to 4.5 ft	to 3 in deep	Slow colonizer, tolerates drying
Water Iris (Iris pseudoacorus)	2, 3	Perimeter	to 3 in deep	Attractive, ornamental
Water Cress (Nasturtium officianale)	Flowing water		to 6 in deep	

Zones listed in table:

1. Deep water pool (1 ft to 6 ft deep).
2. Shallow water bench (6 in to 12 in deep).
3. Shoreline fringe (regularly inundated).
4. Riparian fringe (periodically inundated).
5. Floodplain terrace (infrequently inundated).
6. Upland slopes (seldom or never inundated).

The vegetation planted in and around the wetland should correspond to the hydrology of the wetland. This information is unique to specific geographic locations. Topsoiling of the surface prior to planting may not always be necessary. The wetland plants themselves often produce a substantial amount of organic matter below the ground. Topsoiling may be needed if the soils are composed of mainly clay, rock, or pyritic soils. Although KY-31 Tall Fescue has often been used to reduce erosion, it may displace native grass and meadow species, and possibly overtake some of the wetland. Use of this grass type is questionable because of its aggressive nature (The Center for Watershed Protection, 1994).

REFERENCES

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3. The Center for Watershed Protection, 1994. *Watershed Protection Techniques*, Vol. 1 No. 2, The Center for Watershed Protection, Silver Spring, MD.

4. M. E. Dormann, J. Hartigan, and B. Maestri, 1988. *Retention, Detention, and Overland Flow for Pollutant Removal from Highway Stormwater Runoff: Interim Guidelines for Management Measures*, FHWA/RD-87/056, Federal Highway Administration, Versar, Inc., Springfield, VA.

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7. T. R. Schueler, 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*, Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, DC.

8. B. R. Urbonas, J. T. Doerfer, J. Sorenson, J. T. Wulliman, and T. Fairley, 1992. *Urban Storm Drainage Criteria Manual, Volume 3 - Best Management Practices, Stormwater Quality, Urban Drainage and Flood Control District*, Denver, CO.

9. Ventura Countywide Stormwater Quality Management Program, *Draft BMP CW: Constructed Wetlands*, June 1999. Ventura, CA.

The following is a known location where a Constructed Wetland was installed. The design of the installed wetland in the location may vary from what is recommended in this SUSMP due to its specific circumstances. Los Angeles County does not endorse nor warranty any design used in the location herein. Each individual case may require that the design be tailored to perform properly.

Installed Location (City/Address)	Brand/Manufacturer	Owner/Client
Malibu	N/A	Las Virgenes MWD